



Dorothy Canter  
03/01/99 03:28 PM

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To: Catherine Mccracken@EPA  
cc:  
Subject: Comments on Frequently Asked Questions Document

Catherine

Attached is the Frequently Asked Questions (FAQ) document to which I have added, using the redline/strikeout method, my suggested revisions. There are two areas in which I disagree with ORD's language but have not made changes. For your information, they are the following:

- (1) The ERD presents a hazard characterization of perchlorate, not a risk assessment, since it only deals with the toxicity of the ion/chemical and does not take exposure into account.
- (2) Although the ERD and the FAQ document both talk about the benchmark dose, what was proposed in the ERD was a reference dose, using a minimal "LOAEL" and then multiplying that LOAEL by uncertainty factors.

For the purpose of the FAQ document, these are minor issues, since the document is not a technical report.

At some point, the FAQ document, or some other statement, will need to address the conclusions of the peer review workshop, as presented in the workshop report. Peter has not yet received the draft report from RTI. The contractor is still waiting for input from one or more of the peer reviewers.

Do not hesitate to contact me if you have any questions about my suggested revisions.

Dorothy



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United States  
Environmental Protection  
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# EPA

## Frequently Asked Questions about Perchlorate

### *What is perchlorate?*

The perchlorate ( $\text{ClO}_4^-$ ) ion originates as a contaminant in the environment from the solid salts of ammonium, potassium, or sodium perchlorate. It is quite soluble in water. The perchlorate part of the salts are is quite soluble in water. The resultant anion ( $\text{ClO}_4^-$ ) and is very mobile in aqueous systems. It can persist for many decades under typical groundwater and surface water conditions, because of its lack of reactivity resistance to react with other available constituents.

Subsequent to the development in April 1997 of a new chemical analytic detection methodology in April 1997, which can detect perchlorate at levels of four parts per billion (ppb) and above, perchlorate has been measured at various manufacturing sites and in well water and drinking water supplies in California, Nevada, and Utah. The majority of locations where perchlorate has been detected in the groundwater are in California, associated with 12 facilities which have manufactured or tested solid rocket fuels for the Department of Defense (DoD) or the National Aeronautics and Space Administration (NASA). Two facilities which manufactured ammonium perchlorate in Nevada were found to have released perchlorate to groundwater which is the source for low levels (4 to 16 ppb) in Lake Mead and the Colorado River. This water is used for drinking water supply, irrigation and recreation for millions of people in Nevada, California, and Arizona. Other releases to surface water or groundwater have been detected in Arkansas, Indiana, Iowa, Maryland, New Mexico, New York, Pennsylvania, Texas, Utah, and West Virginia.

Information on other potential sites across the country with potential perchlorate contamination is being gathered from DoD and NASA searches and from EPA information requests made to perchlorate manufacturers. There are 44 states with confirmed perchlorate manufacturers or users, based on EPA information requests. EPA has notified State, Tribal, and local governments when it has evidence of perchlorate manufacture and/or use in their jurisdictions. At this time there has not been a systematic national survey of perchlorate occurrence. The American Water Works Association Research Foundation (AWWARF) is coordinating a survey to characterize possible perchlorate contamination of drinking water sources in areas of high risk. EPA will build upon these survey data and other information in order to discover potential sources and evaluate threats to water resources.

***What are possible sources of contamination?***

Ammonium perchlorate is manufactured for use as the oxidizer component and primary ingredient in solid propellant for rockets, missiles, and fireworks. Large-scale production began in the United States in the mid-1940s. Because of its limited shelf life, it must be periodically washed out of the country's missile and rocket inventory and replaced with a fresh supply. Thus, large volumes of the compound have been disposed of since the 1950s in Nevada, California, Utah, and likely other states. Perchlorate salts are also used on a large scale as a component of air bag inflators. Ammonium perchlorate is also used in the manufacture of matches and in analytical chemistry.

Other uses of perchlorate salts include their use in nuclear reactors and electronic tubes, as additives in lubricating oils, in tanning and finishing leather, as a fixer for fabrics and dyes, in electroplating, in aluminum refining, in rubber manufacture, and in the production of paints and enamels. Chemical fertilizer also has been reported to be a potential source of perchlorate contamination.

***What are concerns regarding exposure to perchlorate?***

Potassium perchlorate was used previously in the United States to treat hyperthyroidism (excessive functional activity of the thyroid gland) resulting from an autoimmune condition known as Graves' disease. Potassium perchlorate is still used diagnostically in this country to measure the discharge of iodine from the thyroid gland ~~test thyroid hormone levels~~ in some clinical settings. The basis for the effect on thyroid hormone function is the competitive inhibition of iodide anion uptake by the thyroid, which results in reduced thyroid hormone production. Thyroid hormone deficiencies can affect normal metabolism, growth and development. Disruption of ~~the~~ thyroid hormone homeostasis (stable equilibrium) has been shown to can also result in the formation of thyroid tumors, particularly in laboratory rats-rodents.

Perchlorate is of concern because of: 1) existing uncertainties in the toxicological database to adequately address the potential for perchlorate to produce human health/ecotoxicological effects at low levels in drinking water; 2) uncertainties regarding the extent of the occurrence of perchlorate in ground and surface waters; 3) the efficacy of different treatment technologies for various water uses; and 4) the extent and nature of ecological impact or(on??) transport and transformation phenomena in various environmental media (this last reason does not make sense to me as written).

***What new information has the EPA released about potential risks to human and ecological health due to perchlorate?***

The external review draft (ERD) of the document entitled *Perchlorate Environmental*

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*Contamination: Toxicological Review and Risk Characterization* was completed December 31, 1998. The document, developed by the U.S. Environmental Protection Agency's (EPA) National Center for Environmental Assessment (NCEA), Office of Research and Development (ORD), ~~will undergo~~ external expert review by ten independent scientists on February 10 and 11, 1999 in San Bernardino, California. The draft presents an updated human health risk assessment as well as an ecological assessment of newly performed studies on the toxicity of perchlorate. Its development is part of a wider interagency effort to address environmental contamination issues related to perchlorate. The purpose of this document is to provide scientific support and rationale for hazard identification and dose-response assessments based on the totality of available ~~emerging~~ data for both human health and ecological effects caused by exposure to perchlorate. It is not intended to be a comprehensive study on the chemical or **toxicological (WHY NOT - IT SHOULD!!!)** nature of perchlorate.

A Federal Register Notice announcing the external peer review meeting and the availability of the draft document was published on January 14, 1999 (64 FR 2492). For any further information on the peer review meeting, refer to the EPA Office of Ground Water and Drinking Water's website at <http://www.epa.gov/ogwdw/ccl/perchlor/perchlo.html>.

#### ***What information is contained in the Perchlorate ERD?***

This ERD presents an updated human health risk assessment as well as a ~~screening~~ ecological assessment of newly performed studies on the toxicity of perchlorate. The human health risk assessment model harmonizes noncancer and cancer approaches to derive a single **proposed** oral risk benchmark based on precursor effects for both nervous system developmental effects and thyroid tumor formation. Both of these are historically established effects of disturbances in the hypothalamic-pituitary-thyroid feedback system. The oral risk benchmark (RfD), as proposed, is protective of potential cancer because of ~~consistently negative results in a suite of genetic toxicology studies performed in the last year~~ new perchlorate data on the lack of genotoxicity and the reversibility of thyroid hypertrophy (increased size of thyroid cells) ~~hyperplasia (???increased activity of the thyroid)~~. These data allowed perchlorate to be characterized as a ~~non-genotoxic~~ indirect anti-thyroid chemical according to current EPA guidance (see Assessment of Thyroid Follicular Cell Tumors at <http://www.epa.gov/ncea/thyroid.htm>).

The proposed oral benchmark is 0.0009mg/kg-day (milligrams/kilogram/day). This value reflects the inclusion of a composite uncertainty factor of 100, ~~although some reviewers suggested that an uncertainty factor of at least 300 would be more consistent with the available data~~

**.(Given that the peer reviewers concluded that it was premature to propose a reference dose or benchmark dose and that the dose proposed in the ERD appears conservative based upon the current data base, I strongly recommend that the preceding statement that I have stricken**

The harmonized RfD is an oral risk benchmark estimate of the amount of perchlorate, which when ingested daily over a lifetime is anticipated to be without adverse health effects (both noncancer and cancer) to humans, including sensitive subpopulations. At the RfD or below, exposures are expected to be safe.

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**out, be removed from the final FAQ.)** Although presented as a point estimate, a benchmark value such as this is typically considered to be an average estimate with uncertainty ranging from 3-fold below to 3-fold above. The confidence in the derivation is medium. If standard default body weight (70 kilograms) and water consumption (2 liters/day) values were applied to the benchmark value to derive an proposed action level, the resulting value (32 parts per billion or ppb) would be slightly above the current range of action levels ( 4 to 18 ppb) based on the previous provisional RfD values. Assessment of ecological screening data suggest that additional research is warranted.

The finalized human and ecological assessments may be used in the future to support development of a health advisory or National Primary Drinking Water Regulation (NPDWR) and cleanup decisions at hazardous waste sites. No systematic survey of perchlorate occurrence or exposure characterization has yet been made and represents a key data gap in the ability to characterize risk.

#### ***What will happen after the peer review meeting?***

Following the peer review meeting, the peer review panel will generate a report detailing their comments and recommendations on the design, conduct and interpretation of the toxicological studies undertaken since May 1997; the quality of the toxicological review document (the ERD); the appropriateness of the proposed hazard characterization and reference dose; and the need for additional studies. This report will be submitted from the peer reviewers to Research Triangle Institute (RTI), an independent organization conducting the peer review under contract to EPA. RTI will then prepare a workshop report, which will be submitted to the EPA's Office of Solid Waste and Emergency Response (OSWER). OSWER will provide this report to various EPA Offices including the EPA's Office of Research and Development (ORD), the Office of Water, and the Regional Offices, and other interested agencies and individuals.

ORD's scientists will consider the comments and recommendations in preparing a revised draft review document. They will also analyze data from the ongoing toxicology studies and studies of human volunteers, once they are completed, and add discussions of these studies to the revised draft document. This revised draft document will serve as the basis for a second external peer review process expected to take place in late 1999. The February 1999 external peer review meeting was an important, but not final, step in the EPA process to EPA of adopting a RfD in its Integrated Risk Information System (see IRIS, below) and considering regulatory action under the Safe Drinking Water Act (see below).

EPA is committed to an objective, open and highly credible peer review process on perchlorate toxicity issues and to the development of a high quality toxicological review document and hazard characterization.

#### ***Hazard Identification and Testing Strategy for Human Health and Ecological Effects***

The human health testing strategy included eight different recommended studies to address

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data gaps and enhance the mechanistic information on the mode of action to provide a comprehensive database on which to arrive at a revised human health risk assessment with greater confidence than previous provisional values. These are described below along with their anticipated role in informing the revised health risk assessment.

- (1) A 90-day oral bioassay study to identify ~~other~~ target tissues ~~in addition to the thyroid~~ in young adult rats; to provide data on the effects of repeated exposures to perchlorate on thyroid hormone levels (T3, T4, and TSH); to evaluate recovery of effects after 30 days; and to screen for some reproductive parameters. This study is considered the minimum data requirement for derivation of an oral RfD.
- (2) A neurobehavioral developmental study in rats to evaluate the potential for functional and morphological effects in offspring from the mother exposed during pregnancy and lactation.
- (3) A segment II developmental toxicity study in rabbits to evaluate the potential for perchlorate to cause birth defects and to provide data on thyroid hormone effects in a second species other than the rat.
- (4) A two-generation reproductive toxicity study to evaluate the potential for perchlorate to cause deficits in reproductive performance in adult rats and for toxicity in the young offspring.
- (5) ADME (Absorption, Distribution, Metabolism, and Elimination) studies to characterize the pharmacokinetics (how perchlorate is absorbed, distributed, metabolized and excreted) of perchlorate in laboratory animals and humans and to provide data necessary to allow construction of models for quantitative description of different internal dose metrics and extrapolation of dose across species (e.g., rat to human).
- (6) Mechanistic studies that characterize the effects of perchlorate on the iodide uptake mechanism across species as a link with the ADME studies to aid in the quantitative extrapolation of dose across species
- (7) Genotoxicity assays to evaluate the potential of perchlorate to cause mutations and other toxic effects at the deoxyribonucleic acid (DNA) and chromosomal level and to assess whether perchlorate causes cancer in rats by a genotoxic or non-genotoxic mechanism. ~~carcinogenicity by evaluating the potential for direct effects on deoxyribonucleic acid (DNA).~~
- (8) Immunotoxicity studies to evaluate the potential for perchlorate to disrupt immune function.

Another potential area of health impact is on ecosystems and via indirect exposure pathways (e.g., agriculture or fishing). Searches of available databases revealed minimal information (before 1998) on the ecological effects of ammonium perchlorate or any of its other salts. In 1998, a battery of ecological screening tests was conducted in laboratory organisms representative of ecological receptors across soil, sediment, and water to evaluate dose-response relationships. These were

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considered to be a tier of tests to give an idea of gross toxicity that would determine the need for and types of tests to be performed in the next tier. The tests did not measure the amount of perchlorate in the tissues of the species being tested. Based on stakeholder input and the need for a more focused battery of tests, the species listed below were selected for the first round of testing. Lettuce was substituted for duckweed because of tribal concerns regarding the sizable lettuce crop along the Colorado River.

- (1) Water flea (*Daphnia magna*) to represent an aquatic invertebrate.
- (2) Water flea (*Ceriodaphnia magna*) to represent an aquatic invertebrates.
- (3) Lettuce (*Lactuca sativa*) to represent a vascular plant.
- (4) Fathead minnow (*Pimephales promelas*) to represent an aquatic invertebrate.
- (5) Earthworm (*Eisenia foetida*) to represent a soil invertebrate.
- (6) Meadow vole (*Microtus pennsylvanicus*) to represent an herbivore.
- (7) Frog Embryo Teratogenesis Assay: *Xenopus*.
- (8) Phytoremediation study to examine uptake, distribution, and degradation in experimental systems with rooted cuttings of woody plants, including willow, Eastern Cottonwood, and eucalyptus.

The development of the ERD and the risk assessment activities regarding perchlorate have been a model for a full and open public process involving several EPA offices, programs, and regions, other federal agencies, states, and the industry and the public. Of particular note is the Interagency Perchlorate Steering Committee (IPSC, see additional information below), a working partnership of government agencies chartered to facilitate identification of the issues and coordinate the exchange of scientific information related to potential perchlorate contamination in the environment.

#### ***How do you get a copy of the ERD?***

The draft document can be downloaded from the NCEA website at <http://www.epa.gov/ncea/perch.htm>. Copies of the document are also available at all EPA Regional Office Superfund Records Centers. Copies of the documents as well as all supporting information, will be available for review at the following locations: EPA Regional Office Superfund Records Centers in Dallas, TX (Region 6), Denver, CO (Region 8) and San Francisco (Region 9); EPA Headquarters Library, Information Resources Center, Washington, DC, and Superfund Docket, Arlington, VA; NCEA Offices in Cincinnati, OH and Research Triangle Park, NC; California Department of Health Services; California Environmental Protection Agency's Office of

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Environmental Health Hazard Assessment; and the Operation Toxicology Branch at Wright-Patterson Air Force Base, Dayton, OH.

***Are there federal regulations about perchlorate?***

The Safe Drinking Water Act (SDWA), enacted by Congress in 1974 and amended in 1986 and 1996, provides the basis for safeguarding public drinking water systems from contaminants that pose a threat to public health. The purpose of SDWA is to protect public health by ensuring that public drinking water systems provide tap water that is safe for drinking and bathing. Within EPA, the Office of Ground Water and Drinking Water (OGWDW) develops National Primary Drinking Water Regulations (NPDWR) to control the levels contaminants that may occur in public drinking water systems. *There is no National Primary Drinking Water Regulation (NPDWR) for perchlorate.*

The 1996 amendments to the SDWA require EPA to publish a list of contaminants that are not currently subject to a NPDWR and are known or anticipated to occur in public water systems. This list, known as the Contaminant Candidate List (CCL), will be the source of priority contaminants for research, guidance development, and selection of contaminants for making regulatory determinations and/or monitoring by the States. The CCL consists of 50 chemical and 10 microbiological contaminants and is divided into two categories: (1) contaminants for which sufficient information exists to begin to make regulatory determinations by 2001, and (2) contaminants for which additional research and occurrence information is necessary before regulatory determinations can be made. *Perchlorate is identified as a contaminant needing additional research in the areas of health effects, treatment technologies, analytical methods, and more complete occurrence data. Perchlorate was placed on the Office of Water's Contaminant Candidate List in March 1998, and noted that it requires additional research and information before regulatory determinations can be made again in 2003.*

***What is IRIS?***

IRIS is an acronym which stands for the Integrated Risk Information System (IRIS), prepared and maintained by the U.S. Environmental Protection Agency. It is an electronic data base containing information on human health effects that may result from exposure to various chemicals in the environment. IRIS was initially developed for EPA staff in response to a growing demand for consistent information on chemical substances for use in risk assessments, decision-making and regulatory activities.

The heart of the IRIS system is its collection of computer files covering individual chemicals. These chemical files contain descriptive and quantitative information in the following categories: (1) oral reference doses and inhalation reference concentrations (RfDs and RfCs, respectively) for chronic noncarcinogenic health effects, and (2) hazard identification, oral slope factors, and oral and inhalation unit risks for carcinogenic effects.

*How is the information in IRIS used in EPA decision making?*

The information in IRIS is intended for use in protecting public health through risk assessment and risk management. These two processes are briefly explained below.

Risk assessment has been defined by the National Research Council (1983) as "the characterization of the potential adverse health effects of human exposures to environmental hazards." In a risk assessment, the extent to which a group of people has been or may be exposed to a certain chemical is determined, and the extent of exposure is then considered in relation to the kind and degree of hazard posed by the chemical, thereby permitting an estimate to be made of the present or potential health risk to the group of people involved.

Risk assessment information is used in the risk management process in deciding how to protect public health. Examples of risk management actions include deciding how much of a chemical a company may discharge into a river; deciding which substances may be stored at a hazardous waste disposal facility; deciding to what extent a hazardous waste site must be cleaned up; setting permit levels for discharge, storage, or transport; establishing levels for air emissions; and determining allowable levels of contamination in drinking water.

Essentially, risk assessment provides INFORMATION on the health risk, and risk management is the ACTION taken based on that information. A complete risk assessment consists of the following four steps: (1) hazard identification, (2) dose-response assessment, (3) exposure assessment, and (4) risk characterization, with risk characterization being the transitional step to risk management.

The information in the Integrated Risk Information System (IRIS) is most useful if applied in the larger context of risk assessment as outlined by the National Academy of Sciences. IRIS supports the first two steps of the risk assessment process; namely, the hazard identification and dose-response assessment steps. The primary qualitative and quantitative health hazard information in IRIS, the oral reference doses (RfDs), inhalation reference concentrations (RfCs), and carcinogenicity assessments, can serve as guides in evaluating potential health hazards and selecting a response to alleviate a potential risk to human health.

The RfD and RfC can be used to estimate a level of environmental exposure at or below which no adverse effect is expected to occur. The RfD or RfC is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime. RfDs and RfCs are based on an assumption of lifetime exposure and may not be appropriately applied to less-than-lifetime exposure situations. RfDs and RfCs are also derived for the noncarcinogenic effects of chemicals that are carcinogenic.

The carcinogenicity assessments in IRIS begin with a qualitative weight-of-evidence judgment as to the likelihood that a chemical may be a carcinogen for humans. This judgment is

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made independent of consideration of the agent's potency. A quantitative assessment, which may include an oral slope factor and oral and/or inhalation unit risks, is then presented. The oral slope factor is an upper-bound estimate of the human cancer risk per mg of agent/kg body weight/day. The unit risk, which is calculated from the slope factor, is an estimate in terms of either risk per ug/L drinking water, or risk per ug/cu.m air concentration.

In general IRIS values cannot be validly used to accurately predict the incidence of human disease or the type of effects that chemical exposures have on humans. This is due to the numerous uncertainties involved in risk assessment, including those associated with extrapolations from animal data to humans and from high experimental doses to lower environmental exposures. The organs affected and the type of adverse effect resulting from chemical exposure may differ between study animals and humans. In addition, many factors besides exposure to a chemical influence the occurrence and extent of human disease.

Any alteration to an RfD, RfC, slope factor or unit risk as they appear in IRIS (for example, the use of more or fewer uncertainty factors than were applied to arrive at an RfD) invalidates and distorts their application in estimating the potential health risk posed by chemical exposure.

Each reference dose/concentration and carcinogenicity assessment has been reviewed by a group of EPA health scientists using consistent chemical hazard identification and dose-response assessment methods. These methods are discussed or referenced in the Background Documents. It is important to note that the information in IRIS may be revised by EPA, as appropriate, when additional health effects data become available and new developments in assessment methods are adopted.

For more information on the process for developing information for IRIS, contact the Risk Information Hotline in EPA's National Center for Environmental Assessment, Cincinnati, OH (Telephone 513-569-7254 or fax 513-569-7159 or email RIH.IRIS@epamail.epa.gov).

#### **Are there state regulations about perchlorate?**

In 1997, California established an action level of 18 parts per billion (ppb) for perchlorate **(would it be appropriate to add "for drinking water supplies" here?)** Perchlorate concentrations lower than 18 ppb are not considered to pose a health concern for the public, including children and pregnant women. CA DHS advises water utilities to remove drinking water supplies from service if they exceed the 18 ppb action level. If the contaminated source is not removed from service due to system demands and if drinking water that is provided by the utility exceeds the action level, CA DHS will advise the utility to arrange for public notification to its customers. On August 1, 1997, CA DHS informed drinking water utilities of its intention to develop a regulation to require monitoring for perchlorate as an unregulated chemical. Legislative action to establish a state drinking water standard for perchlorate has been introduced but has not been brought to a vote (CA Senate Bill 1033). **(...but was vetoed in 1998.)**

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In August, 1997, the Nevada Division of Environmental Protection determined that the health-based action level of 18 ppb, as established in California, would be the recommended action level for cleanup pending a more current risk assessment.

No other state is known to have adopted action levels for perchlorate primarily since levels greater than 18 ppb have not been found in water supplies in other States.

### *Analytical Methods Issues*

As noted above, the first critical data needed for a comprehensive risk characterization is accurate information on occurrence: where the contamination occurs, the nature (type) and extent (magnitude) of the exposure. Occurrence survey studies require a reliable and accurate analytical method for detecting perchlorate in drinking water and various aquifer types or other environmental media (e.g., irrigated food crops). Ion chromatography (IC) is the state-of-the-art technology for analysis because historical methods based on gravimetry, spectrophotometry, or atomic absorption are non-specific for perchlorate. There are several existing IC methods, including the recent analytical method developed by the California Department of Health Services (CA DHS), Dionex, and one developed by the Air Force Research Laboratory/Operational Toxicology Branch (AFRL/HEST). These methods depend upon retention time in a standard to identify any peak with the same or similar retention time as perchlorate in a water sample. The robustness of existing IC methods for the analysis of perchlorate in water with high total dissolved solids has been questioned. Research is underway that will evaluate the variability, reproducibility, accuracy and precision of the IC methods across laboratories and to determine the appropriate concentration ranges for measurement.

An increasing number of commercial and government laboratories have adopted the improved analytical methods, leading to further discoveries of perchlorate contamination and an increase in monitoring water supplies. Development of a formal published method documenting the reproducibility and limitations of the technique is expected to facilitate the acceptance of perchlorate testing at low concentrations by laboratories across the country. The need for a reporting limit of 4 ppb taxes the sensitivity and reproducibility of the current IC method. A collaborative study of existing IC methods is planned for the near future. Work is also being planned to develop different analytical techniques to confirm the results of the IC method.

Monitoring water supplies and identifying possible sources of perchlorate contamination are not the only needs for analytical capability. A reliable and accurate method for analysis of perchlorate is essential for research in human health risk assessment, treatment technologies, and ecological toxicology. Results of these assessments may place additional requirements on analytical methods.

The analytical subcommittee of the Interagency Perchlorate Steering Committee (IPSC) has coordinated a collaborative study of the existing IC method and its variations. This method has been used to measure perchlorate in all water supplies where perchlorate has been tentatively

identified. The subcommittee is composed of four scientists from EPA, the states of California and Utah, and the United States Air Force. The study design evaluated the within laboratory precision (repeatability), between laboratory precision (reproducibility), method accuracy (bias), detection limit, and sensitivity. The results of this collaborative study will serve as a basis to focus future research and method development, with the overall goal to publish a standardized method or methods for low level perchlorate determination.

### ***Treatment Technologies Issues***

Treatment technologies capable of removing perchlorate from water are urgently needed. No one technology or process will likely provide an effective solution for every occurrence of perchlorate contamination in water supplies due to a large number of independent variables. Different technology may also be developed depending upon the intended use of the treated water (e.g., drinking water versus agricultural application). Treatment technologies and processes have been developed by industry and the Air Force Research Laboratory, Materials and Manufacturing Directorate (AFRL/MLQE) to recover perchlorate for reuse and to treat residual wastewater containing high concentrations of perchlorate, i.e. 500-10,000 parts per million (ppm), from the manufacture and maintenance of rocket motors. Research is underway to develop technologies that meet the new challenge of treating low-concentration (5 ppb to 500 ppm) perchlorate contamination present in ground and surface water supplies.

Water utilities, in particular, need treatment methods that can reliably reduce perchlorate concentrations to low or non-detectable levels. Because the perchlorate ion is nonvolatile and highly soluble in water, it cannot be removed from water by conventional filtration, sedimentation, or air stripping. It appears to be only weakly removed by activated carbon. To be useful, a treatment method must be cost-effective, acceptable to regulatory agencies and the public, cause no other water quality problems, and minimize waste generation. The only option available for reducing perchlorate levels in contaminated water supplies is by blending uncontaminated supplies with those that containing perchlorate. In addition, the degree to which treatment options need to be developed is a function of the forthcoming results of the toxicology and health affects data and resulting peer reviewed reference dose for drinking water.

A few promising technologies are being developed for removal of perchlorate. Some are commonly used in water treatment, others less so. An anaerobic biochemical process has received the most attention, but reverse osmosis and ion exchange are also capable of removing perchlorate. Studies are underway to evaluate the cost, effectiveness, and implementability of these technologies. Technologies are grouped into three categories: physical, chemical, and biochemical.

#### ***Physical Processes (Ion Exchange, Reverse Osmosis, Nanofiltration)***

There is no doubt that physical processes such as ion exchange and reverse osmosis can remove perchlorate from water. Of the two processes, ion exchange, in which the perchlorate ion is replaced by an innocuous anion (e.g., chloride), is currently receiving the most attention. Ion

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exchange technologies have not yet been used to remove low levels of perchlorate from drinking water supplies, but have been widely used in drinking water treatment to remove higher concentrations of nitrate, an anion similar to perchlorate. Perchlorate and nitrate are weakly hydrated in solution, and similar technologies are expected to be applicable to the treatment of both ions. In California's San Gabriel Valley, the Main San Gabriel Basin Watermaster is the primary sponsor of bench and pilot-scale tests of the performance of ion exchange technologies. The San Gabriel Valley study is evaluating the cost and effectiveness of removing approximately 30 to 200 parts per billion (ppb) perchlorate from groundwater.

Nanofiltration and reverse osmosis will also remove perchlorate, but at unknown cost. Pilot-scale tests completed by Harvey Mudd College for the Metropolitan Water District of Southern California have shown that nanofiltration can reduce perchlorate from 18 ppb to less than 4 ppb in a contaminated surface water supply, but at undetermined cost. In addition, the Southern Nevada Water Authority reportedly achieved satisfactory results in tests of in-home reverse osmosis units with trained operators.

#### *Chemical Processes (Chemical Reduction, Ozone-Peroxide)*

Perchlorate is a highly oxidized compound (i.e., it has a strong affinity for electrons). One might therefore expect that perchlorate could be destroyed by adding a chemical reducing agent to convert its chlorine atoms to chloride, a harmless component of table salt. Unfortunately, the chemical reaction between perchlorate and commonly used reducing agents is too slow to be of practical use. Perchlorate may react with more exotic reducing agents, such as titanium, vanadium, molybdenum, or ruthenium, but these chemicals are likely to be too unstable or toxic to be practical for water treatment. Catalysts that could selectively speed the destruction of perchlorate have not been identified.

Ozone-peroxide treatment appears to have minimal effect on perchlorate in water, but ozone-peroxide followed by liquid phase carbon treatment has been shown to remove perchlorate from groundwater at a water supply well in the San Gabriel Valley. EPA is planning additional tests to evaluate the long-term effectiveness, reliability, and cost of the process. The American Water Works Association Foundation may also fund additional evaluations of this process as part of its \$2 million federally funded perchlorate treatment research program.

#### *Biochemical Processes (Anaerobic Biochemical Reduction)*

To date, more effort has been directed at developing an anaerobic biochemical reduction process than any other treatment option. In the biochemical reduction process, microbes are used to convert perchlorate to a less toxic or innocuous form. Microbes have been used for decades in the treatment of some drinking water supplies, as part of a process known as slow sand filtration.

The Air Force Research Laboratory, Materials and Manufacturing Directorate began development of biochemical reactor systems for the treatment of high level perchlorate-

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contaminated wastewater, i.e. 1000 to 10,000 parts per million (ppm), more than eight years ago. A production-scale, continuous-stirred-tank-reactor system began treating wastewater from rocket motor production operations in Utah in 1997. Applying the same concept, pilot-scale tests of an anaerobic fluidized bed bioreactor were completed at the Aerojet Superfund site near Sacramento, California in 1996. The tests demonstrated that a bioreactor could reduce perchlorate concentrations in groundwater from over 5000 ppb to the low hundreds of ppb. A 4000-gallon per minute (gpm) flow-through bioreactor was brought online in late 1998 to treat contaminated groundwater before recharge to the aquifer.

Additional pilot-scale tests were recently completed by the Baldwin Park Operable Unit Steering Committee at one of the San Gabriel Valley, California Superfund sites, where groundwater contaminated with approximately 150 ppb perchlorate must be treated. Results from the San Gabriel Valley tests are encouraging; perchlorate has been reduced to nondetectable levels. The bioreactor also removed nitrate, which is present in the aquifer at 20 to 30 ppm (as NO<sub>3</sub>). Larger-scale testing at 500 to 1000 gpm will continue at a perchlorate-contaminated drinking water supply well in the San Gabriel Valley. Ultimately, a perchlorate treatment facility with the capacity to treat 20,000 gpm is expected to be built with some or all of the treated water supplied to local drinking water utilities. Although bioreactors appear capable of removing low level perchlorate contamination from drinking water supplies, the cost, reliability, and public acceptance of this technology are not well established.

The Air Force Research Laboratory has also initiated an effort to isolate enzymes from the microorganism responsible for perchlorate reduction. If this effort is successful, enzymes might be used in a fixed-bed reactor system to selectively remove perchlorate over a range of concentrations.

Only within the last two years has a substantial effort been directed at the development of perchlorate-removal technologies that could potentially be used to treat perchlorate-contaminated drinking water supplies. Pilot-scale studies of two or three promising technologies will soon be complete, and performance data from a full-scale anaerobic biochemical treatment system should be available. In 2001, results from the \$2 million American Water Works Association Research Foundation research effort will also become available.

#### ***What is the Interagency Perchlorate Steering Committee (IPSC)?***

The Interagency Perchlorate Steering Committee (IPSC) was formed in January 1998 and is now a partnership of representatives from 18 different government agencies. Its purpose is to ensure an integrated approach to addressing perchlorate issues and to inform and involve stakeholders about developments in the technical and regulatory arenas. Four EPA representatives serve on the Executive Committee of the IPSC and EPA representatives serve on all of the subcommittees of the IPSC (health effects/toxicity, ecological impacts/transport and transformation, treatment technology, analytical, communications and outreach, and external peer review). It should be noted that the assessment effort for perchlorate was accomplished in an extraordinarily expedited time frame through the partnership of the IPSC membership.

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As of August 1998, the following agencies are members of the IPSC: U.S. Environmental Protection Agency, Department of Defense, Agency for Toxic Substances and Disease Registry, National Institute for Environmental Health Sciences, National Aeronautics & Space Administration, Bureau of Indian Affairs, Arizona Department of Environmental Quality, Arizona Department of Health Services, California Department of Health Services, Nevada Division of Environmental Protection, Texas Natural Resource Conservation Commission, Utah Department of Environmental Quality, Utah Department of Health Laboratories, Cocopah Tribe, Colorado River Indian Tribes, Fort Mojave Tribe, Chemehuevi Tribe, Quechan Tribe.

**U.S. Environmental Protection Agency Contacts for Additional Information**

Peter Grevatt, Office of Solid Waste and Emergency Response  
U.S. Environmental Protection Agency  
401 M Street SW (MS-5103)  
Washington, DC 20460  
Tel: 202-260-3100  
Fax: 202-401-1496  
Email: [grevatt.peter@epa.gov](mailto:grevatt.peter@epa.gov)

Annie M. Jarabek, National Center for Environmental Assessment  
U.S. Environmental Protection Agency, Office of Research and Development (MD-52)  
Research Triangle Park, NC 27711  
Tel: 919-541-4847  
Fax: 919-541-1818  
E-Mail: [jarabek.annie@epa.gov](mailto:jarabek.annie@epa.gov)

Kevin Mayer, Superfund Division  
U.S. Environmental Protection Agency, Region 9  
75 Hawthorne Street (SFD-7-2)  
San Francisco, CA 94105-3901  
Tel: 415-744-2248  
Fax: 415-744-2180  
Email: [mayer.kevin@epa.gov](mailto:mayer.kevin@epa.gov)

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Michael Osinski, Office of Ground Water & Drinking Water

U.S. Environmental Protection Agency

401 M Street SW (MS 4607)

Washington, DC 20460

Tel: 202-260-6252

Fax: 202-260-3762

Email: osinski.michael@epa.gov

**Others??**

**McCracken, Pia, Praskins, Sakata, Sprenger, Tuxen, Urbansky?**

**U.S. Environmental Protection Agency World Wide Web Sites**

EPA Perchlorate Web site: <http://www.epa.gov/ogwdw/ccl/perchlor/perchlo.html>

EPA (NCEA) ERD Web site: <http://www.epa.gov/ncea/perch.htm>